THE EFFECT OF REPRESENTATIVE TASK DESIGN ON GROUND REACTION FORCES PRODUCED BY ADOLESCENT RUGBY PLAYERS

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Our primary aim in this study was to investigate differences in the ground reaction forces (GRFs) produced when adolescent rugby players performed match-reflective tasks of increasing degrees of representativeness. Fourteen male players performed three tasks; a straight jog, an anticipated cut and an unanticipated cut. These tasks were performed in four different conditions; landing with their dominant or non-dominant leg, while carrying or not carrying a rugby ball. Greater GRFs were recorded during both the weight acceptance and late push-off phases of the cutting tasks compared with the straight jog and during the push-off phase when the direction of the cut was anticipated. Carrying a ball, however, did not affect the GRFs recorded. These findings highlight the importance of employing representative task design when assessing performance and designing practice.

KEYWORDS: cutting, dominant leg, soft feet, statistical parametric mapping.

INTRODUCTION: Rugby union is a predominantly open, running game requiring players to perform dynamic cutting movements when evading opposition tackles and creating space to run into. The dual requirement of rapid whole-body deceleration followed by acceleration in the opposing direction within a cutting movement, places large loads on the lower-body in all three planes (Taylor et al., 2017). Coaches therefore consider the demonstration of "soft feet" (the ability to move effectively while generating low GRFs) to be an important attribute of rugby union players in order to land safely, thereby reducing injury risk, and to also effectively initiate a dynamic change of direction (Taylor et al., 2017).

Given the perceived importance of "soft feet", practice activities designed to develop this skill are an important feature of an adolescent player's training. However, researchers have suggested that movement assessments to guide practice should be conducted in settings that faithfully represent the competitive environment, i.e., conditions that mimic those to which the athlete has adapted (Pinder et al., 2011). In particular, the open and varied nature of rugby match play means that players often need to make quick cutting movements in either direction under time constraint. Therefore, it is important to understand whether the "softness" of a player's landing is affected by differences in the task, such as whether the direction of the movement is predetermined, if they are carrying a rugby ball or from which leg it is performed. Our primary aim was to investigate differences in the GRFs produced when adolescent rugby players performed tasks of increasing degrees of representativeness. A secondary aim was to determine whether leg dominance affected GRFs produced across these tasks.

METHODS: Fourteen male adolescent rugby players (aged 13 ± 1 years, 58.3 ± 11.8 kg, 1.66 ± 0.13 m), all of whom trained with a professional rugby academy, volunteered to participate in the study which was approved by the St Mary's University ethics committee. Participant and parental consent was obtained prior to the study commencing.

Following a self-directed warm-up and a familiarisation phase, participants performed five trials of three different tasks in four different conditions (totalling 60 trials) in a randomised order, on a running track in an indoor laboratory. The three tasks were a 10.0 m jog straight down the track, a 5.0 m jog followed by a 45° side-step cut in a predetermined direction (told to the participant prior to the trial) and a 5.0 m jog followed by an unanticipated 45° side-step cut (the direction of the cut was unknown to the participant until 2.5 m into the jog and indicated by a random light stimulus). A force platform (Kistler 9287BA, 1000 Hz) was embedded into the track, 5.0 m from the start line, and the participants were required to land on the platform with either their dominant or non-dominant leg (conditions 1 and 2). For both the anticipated and unanticipated cutting trials, it was from this step on the force platform that the cut was performed (if moving to the left-hand-side they would land and push off from the platform with their right leg and vice versa). A FITLIGHT Trainer™ (FITLIGHT Sports Corp, Canada) was used to indicate the direction of movement during the unanticipated cutting trials. One light was placed 2.5 m from the start line which, when the participant jogged past it, triggered a light placed at a 45° angle on either the left or right-hand-side of the force platform to illuminate and determine the direction of the cut. The direction of the cuts was randomised. Half of the trials were performed with the participants carrying a standard size 5 Gilbert rugby ball as they would in a match situation, and the other half without (conditions 3 and 4). The jogging velocity of all trials was controlled using timing gates (Brower TC wireless timing system, Utah) placed 2.0 m apart, 1.5 m from the start line and the force platform. All trials were required to be within 10% of 0.7 s (~2.86 m/s, comparable to a fast jog; Toda & Murakami, 2015).

Three-dimensional GRF data were filtered at 125 Hz using a fourth order zero-lag Butterworth filter with endpoints padded (20 point reflection) and time-normalised to 101 samples using an interpolating cubic spline from foot contact (the frame when vertical force was first > 10 N; 0%) to toe-off (the frame when vertical force was next < 10 N; 100%). Resultant GRF was calculated using Pythagorean theorem. A mean of the five trials in each condition across the three tasks was calculated and normalised to the participant's body weight.

Peak resultant GRF values were extracted from the data and a three-way repeated measures ANOVA was conducted to identify main and interaction effects in the force produced across the three tasks and the four conditions (SPSS statistics 24). A Bonferroni post-hoc test was then conducted if a main effect of task was observed, with paired sample t-tests used to compare between conditions. The complete time-histories were also compared between the trials using a statistical parametric mapping three-way repeated measures ANOVA, followed by the post-hoc tests described above. A significant difference was identified if $p < 0.05$.

RESULTS: Analysis of the discrete data revealed a significant main effect of task ($p = 0.001$), whereby a significantly greater peak GRF was recorded in the anticipated cuts compared with both the jogs and the unanticipated cuts ($p = 0.003$ and $p = 0.001$, respectively; Table 1). However, there was no difference in the peak GRF recorded in the jogs and unanticipated cuts ($p = 1.000$; Table 1). There was also no significant difference in the peak GRF recorded when participants landed on their dominant compared with their non-dominant leg ($p = 0.780$; Table 1), or when they completed the trials carrying a rugby ball and when not ($p = 0.876$; Table 1).

Table 1: Peak resultant ground reaction force (GRF) recorded during ground contact for each task, when landing on the dominant or non-dominant leg and with or without a ball (mean ± SD).

	Peak GRF (BW)		
	Jog	Anticipated Cut	Unanticipated Cut
Non-dominant Leg			
No Ball	2.48 ± 0.27	2.75 ± 0.25*	2.62 ± 0.24
Ball	2.52 ± 0.22	2.74 ± 0.28*	2.58 ± 0.16
Dominant Leg			
No Ball	2.55 ± 0.18	2.80 ± 0.37*	2.45 ± 0.28
Ball	2.55 ± 0.17	2.71 ± 0.19*	2.58 ± 0.20

* indicates a significant difference between the anticipated cuts and the two other tasks ($p < 0.05$).

When comparing the GRF time-histories, a significant main effect was identified for both task ($p = 0.003$) and landing leg ($p < 0.001$), but there was no effect of ball carry ($p > 0.05$) or any interaction effects (p > 0.05). Post-hoc analysis revealed significantly greater GRF was produced during the initial 25% and between 50 and 95% of ground contact in the anticipated cuts compared with the jogs (p < 0.001; Figure 1b). A significantly greater GRF was also recorded during the initial 20% and final 30% of ground contact for the unanticipated cuts compared with the jogs (p < 0.001; Figure 1d). When comparing the cutting tasks, significantly greater GRF was observed in the unanticipated cuts at ~5% of ground contact (p = 0.016; Figure 1f), but between 15-20% and 30-80% of ground contact, the anticipated cuts produced significantly greater GRF (p = 0.001 and p < 0.001, respectively; Figure 1f).

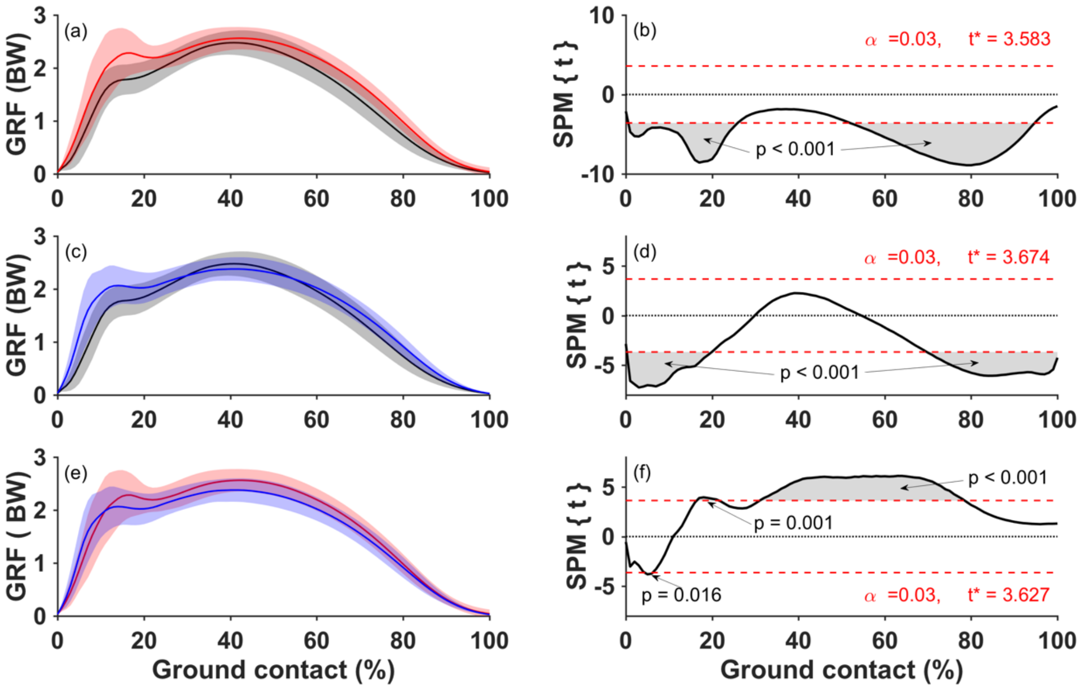

Figure 1: The mean resultant ground reaction force (GRF) time-histories (a,c,e) from foot contact (0%) to toe-off (100%) and associated SPM{t} curves (b,d,f) from the post-hoc analysis comparing the jogging (black), anticipated (red) and unanticipated cutting (blue) trials.

Comparison of the GRF time-histories when the dominant leg landed on the force plate and when the non-dominant leg was used showed that significantly greater GRF was recorded in the non-dominant leg trials between 15 and 22% of ground contact (p < 0.001; Figure 2b).

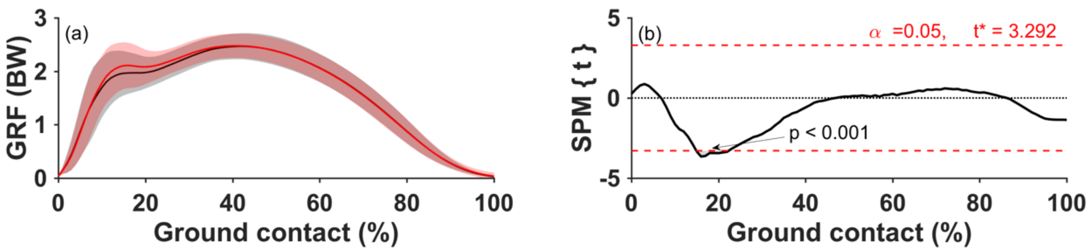

Figure 2: The (a) mean resultant ground reaction force (GRF) from foot contact (0%) to toe-off (100%) when landing with the dominant (black) and non-dominant leg (red) and (b) the SPM{t} curve from the post-hoc analysis.

DISCUSSION: Significantly greater peak GRF was produced when participants performed an anticipated cutting movement towards a predetermined side, compared with when they jogged in a straight line or performed an unanticipated cutting movement. The leg from which the movement was performed was found to have no effect on the peak GRFs produced, nor did whether the participant carried a rugby ball. However, analyses of the complete GRF time-histories revealed further differences, with greater force produced during the weight acceptance (~0-20% ground contact) and late push-off (push-off defined as ~20-100% ground contact) phases in the unanticipated cuts compared with the straight jogs and during the weight acceptance phase when landing with the non-dominant leg compared with the dominant leg.

The significantly greater forces produced in both cutting tasks compared with the straight jogs are likely reflective of the different task requirements as well as the instruction given to the players to “attack the space” following the change of direction, as they would do in a match. The requirement to change direction when cutting meant the players produced significantly greater force during the weight acceptance phase in order to decelerate themselves, before then pushing off harder to accelerate away. These greater forces likely represent an increased injury risk to the players when performing cutting movements compared with jogging (Taylor et al., 2017), but this is unlikely to extend to a comparison of the two cutting tasks given the additional lower-limb mechanical risk factors associated with unanticipated cutting that were not measured in the present study. Furthermore, when players were required to react to a stimulus to determine the direction of their movement, the GRF was significantly reduced throughout the push-off phase compared with when they were able to prepare for the cut. Considering the unpredictable nature of rugby, performing cutting movements in response to a stimulus would seem to more closely represent the competitive environment. The observed differences between the two tasks highlight the need to assess and train adolescent players to develop “soft feet” in more open and varied environments that represent match scenarios.

Additional considerations required when designing representative practice include whether the dominant or non-dominant leg is used to push off from and whether players should carry a rugby ball, to better reflect the demands of the sport. Our results indicate that when using the non-dominant leg, significantly greater force is produced during the weight acceptance phase, which may increase the likelihood of injuries such as anterior cruciate ligament tears (Sigward et al., 2006). Therefore, it is suggested that coaches should ensure all training is performed using both legs, or specific training interventions should be employed to reduce the asymmetry observed. In contrast, carrying a ball was found to have no effect on the GRF, and so it is not suggested that one must be included in such practice activities.

CONCLUSION: This study identified differences in the GRF produced by adolescent rugby players when performing a jog, an anticipated cut and an unanticipated cut from both the dominant and the non-dominant legs and when carrying a rugby ball and when not. When cutting, players produced significantly greater force during both the weight acceptance and late push-off phases compared with a straight jog. Players also produced significantly greater force throughout the push-off phase when they already knew the direction of the cut as opposed to when reacting to a stimulus. These findings highlight the importance of representative learning design when training the “soft feet” characteristic of rugby players. Future research should consider developing these methods further, providing players with a more match-representative stimulus such as a video projection of an opponent which they are required to react to, or investigate the differences in the individual components of the GRF to better understand the different movement patterns.

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ACKNOWLEDGEMENTS: The authors would like to thank the Academy coaches and players of London Irish Rugby Football Club for supporting and participating in this study.